United States Patent [19]

Rupp

[11] **3,824,742**

[45] **July 23, 1974**

[54] **TORIC SURFACE GENERATING METHOD AND APPARATUS**

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[22] Filed: **July 7, 1972**

[21] Appl. No.: **269,664**

[52] **U.S. Cl.** **51/54,** 51/284

[51] **Int. Cl.** **B24b 1/00,** B24b 13/02

[58] **Field of Search** ..... 51/284, 33 R, 33 W, 55, 51/54, 46, 96, 124 R

[56] **References Cited**

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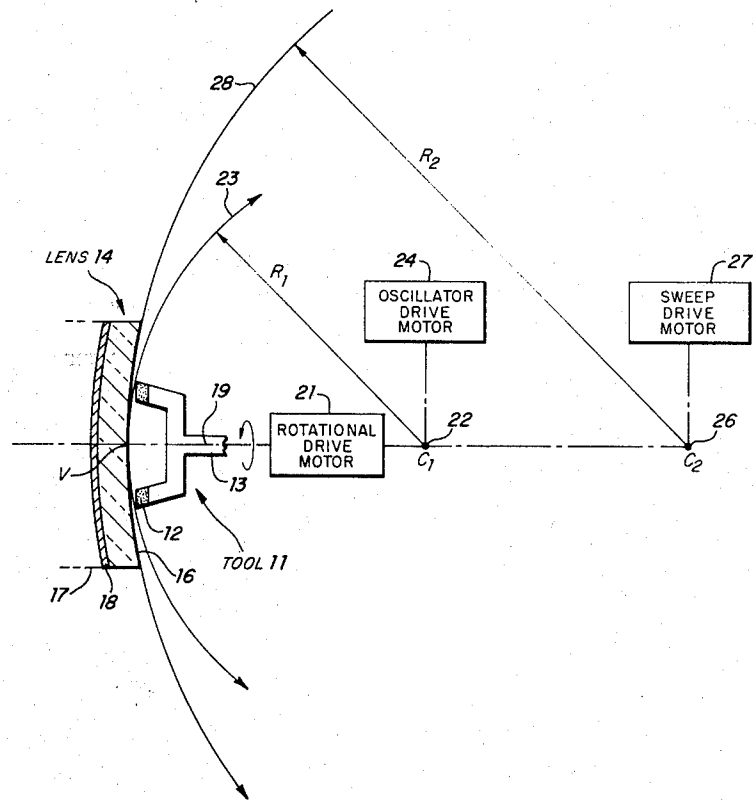
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[57] **ABSTRACT**

Method and apparatus for generating a true toric surface on a lens or other work piece. In accordance with the invention, a cup-shaped surfacing tool is adapted to be moved across a lens blank in a compound motion comprised of an oscillating movement in a first curved path having a radius equal to the radius of curvature desired in the direction of one major meridian of the surface coupled with a sweeping movement in a second curved path having a radius equal to the radius of curvature desired in the direction of the second major meridian of the surface. The tool is aligned relative to the lens surface such that the oscillating movement will be within a plane parallel to the tool axis such that substantially the entire abrasive surface of the tool will operate on the lens surface. This will avoid the formation of ridges on the surface and, at the same time, permit the generation of high quality toric surfaces of any desired curvature with a single tool and with relatively simple kinematics.

14 Claims, 3 Drawing Figures



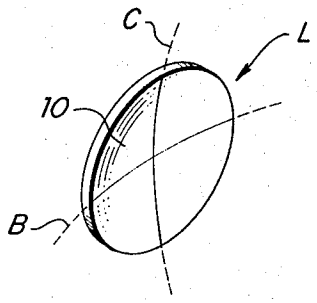


FIG. 1.

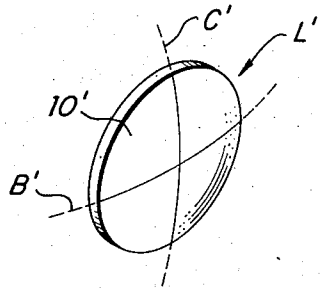


FIG. 2.

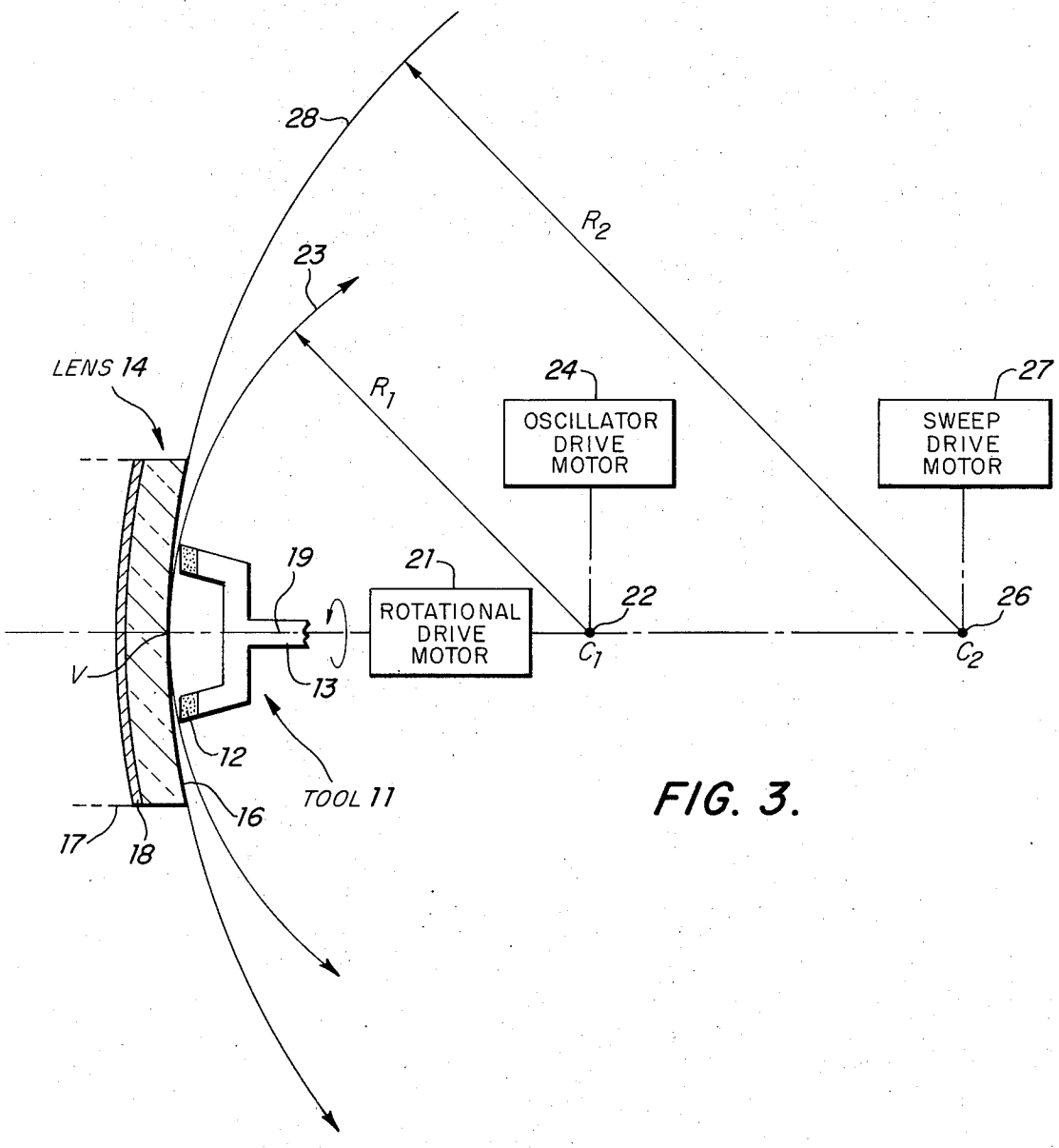


FIG. 3.

TORIC SURFACE GENERATING METHOD AND APPARATUS

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a method and apparatus for generating optical or other surfaces. More specifically, the present invention relates to a method and apparatus for generating a true toric surface on a lens.

2. Description of the Prior Art

A toric surface is a surface of compound curvature in which the curvature measured along a first major meridian of the surface is of a different radial dimension than when measured along a second major meridian normal to and passing through the first meridian. Such surfaces are important in many fields and are of particular value in the design of ophthalmic lenses wherein they are useful in correcting astigmatic defects.

Because of their importance to the ophthalmic field, various techniques have been developed in the past to generate such surfaces. Perhaps the most common technique is to generate the surface with a tool having an abrading face precisely preformed to the toric shape desired on the lens. By appropriately moving such a tool relative to the lens surface, the surface will gradually assume substantially the shape of the abrading face.

Although such a process will produce an accurate toric surface, it is not fully satisfactory. In the ophthalmic area it is necessary to provide lenses with a large number of different curvatures in order to adequately satisfy the prescriptive requirements of all patients, and, since each tool is preformed to generate only a single toric surface, it becomes necessary to stock, service, recondition and replace large numbers of differently shaped tools. This obviously results in a significant amount of expense and inconvenience.

Because of this problem, efforts have been made to utilize a so-called "universal" or cup-shaped generating tool by which toric lens surfaces of different curvatures may be generated with the same tool. Typically, such a tool is tilted relative to the lens blank surface and its edge swept across the surface along a curved path. The radius of curvature of the curved path is selected to correspond to that desired along one major meridian of the lens while the angle at which the tool is tilted relative to the lens blank surface determines the curvature in the direction of the second major meridian. This technique, however, will not produce a true toric surface. In actuality, the edge of the tilted tool, as it is presented to the lens, will be inherently elliptical in shape and this will produce an elliptical error in the lens curvature in the direction of the second major meridian, particularly near peripheral areas of the lens. To correct the lens, follow-up grinding or truing operations are necessary.

In order to eliminate this elliptical error, it has been suggested to oscillate the tilted tool back and forth in a second curved path transverse to the first sweeping path (See U.S. Pat. No. 2,633,675). This procedure will produce a substantially true toric surface and eliminate the elliptical error, however, it will also produce grooves or ridges on the lens surface which are difficult to remove. Thus, this procedure still necessitates uneconomical fine grinding operations to make the lens suitable for ophthalmic use.

In order to avoid the formation of ridges, a technique illustrated in U.S. Pat. No. 3,624,969 was developed. This patent teaches that by appropriately revolving the tool around a point on the lens as it is being swept thereacross, a good quality true toric surface may be produced. The obvious difficulty with this technique is its complexity, both as to the type of movement required and with regard to the tooling needed to produce that movement.

In general, a suitable technique is not availabe in the prior art that will permit a true toric surface to be generated in a simple manner with a universal cup-shaped grinding tool, and that will produce surfaces of high quality without requiring complex or expensive equipment or extensive follow-up surface finishing.

SUMMARY OF A PREFERRED EMBODIMENT OF THE PRESENT INVENTION

By the present invention many of the inadequacies of the prior art have been obviated by providing a novel method and apparatus for generating a true toric surface on a work piece. In accordance with a preferred embodiment of the invention, a true toric surface may be generated on a lens blank by oscillating a cup-shaped tool back and forth across the surface of the lens blank in a first curved path having a radius equal to the radius of curvature desired along one major meridian of the lens surface while simultaneously sweeping the oscillating tool across the lens blank in a second curved path having a radius equal to the radius of curvature desired along the other major meridian of the lens surface. More specifically, the tool is oscillated back and forth in a plane that is parallel to and preferably includes the central axis of the tool as it is swept across the lens blank about an axis that extends through the vertex axis of the lens surface desired.

By designing the kinematics of the system in this way, a true toric surface will be generated on the lens while, at the same time, the problems of the prior art may be substantially reduced. Initially, with the present invention the tool is not tilted relative to the lens surface as in the prior art (e.g. U.S. Pat. No. 2,633,675). This means that the tool will not present a single edge to the lens which can result in the formation of ridges or grooves on the lens and which necessitates follow-up treatment to the blank. In addition, with the above-described kinematics, the particular curvatures to be generated on the lens surface are a function only of the radii of the curved paths along which the tool is moved and are not a function of any particular angular relationship between the tool and the lens surface or of the effective tool diameter itself which may change due to wear. This not only simplifies alignment of the system but also reduces the complexity of the motions required as well as the tooling needed to produce the motions.

Furthermore, in the system illustrated, for example, in U.S. Pat. No. 2,633,675, it is necessary that the oscillating movement of the tool be in a plane perpendicular to the sweeping movement. This is not necessary in the present invention and, in fact, either movement may be at any angle relative to the other and selected on the basis of other considerations to optimize tool performance. This is because, in the present invention, substantially the entire abrading surface of the tool is being

used to perform the surfacing operation as opposed to simply an edge thereof as in the prior art.

In general, the present invention provides a method and apparatus that will rapidly and accurately generate a true toric surface on a lens. It may be readily adapted to the grinding as well as the polishing of lenses, and will produce lenses acceptable in the ophthalmic field. Yet further features and advantages of the present invention will be set forth in detail hereinafter along with a detailed description of the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. 1 and 2 schematically illustrate toric concave and toric convex surfaces, respectively, on a lens.

FIG. 3 illustrates in schematic cross-section form, the kinematics in accordance with a preferred embodiment of the present invention for generating a true toric concave surface on a lens.

DETAILED DESCRIPTION OF THE DRAWINGS

FIGS. 1 and 2 illustrate lenses having concave and convex surfaces, respectively, upon which true toric shapes have been generated. As can be seen in FIG. 1, lens L has been provided with a concave surface 10 that is of true toric shape in that it has a spherical curvature in the direction of both major meridians B and C but that the curvatures in the direction of each meridian are of different radius. In the ophthalmic field, meridian B is referred to as the base meridian and is generally of a longer radius of curvature than meridian C which is perpendicular to meridian B and is called the cylinder meridian. In a toric lens, the curvature in any part of the lens surface measured in the direction of the base meridian is referred to as the base curve while the curvature of the lens surface measured in the direction of the cylinder meridian is referred to as the cross curve.

FIG. 2 illustrates the convex surface of a lens and employs primed reference numbers and letters corresponding to those used in FIG. 1 to denote similar components. This Figure is provided simply to illustrate that a toric surface may also be applied to the convex surface of a lens if desired. Although the following embodiment will relate to the generation of a toric concave surface, it should be understood that it could also be employed to generate a convex toric surface with only minor modification and that the present invention is intended to encompass both operations.

As described previously, the present invention relates to a novel kinematic motion between a lens blank and a "universal" cup-shaped grinding tool that will enable a true toric surface to be generated on the lens blank without necessitating complex movements and without requiring follow-up treatment to the surface. This kinematics is illustrated schematically in FIG. 3.

In FIG. 3, reference number 11 generally refers to a cup-shaped tool which may be of conventional design. This tool is provided with the usual surface 12 of, for example, bonded diamond particles, capable of grinding or polishing the lens surface when moved relative thereto. This tool is supported through spindle 13 to suitable support and drive structure as will be explained in detail hereinafter.

Reference number 14 refers generally to a lens blank having a surface 16 upon which the desired concave toric shape is to be generated. This lens blank is secured to a suitable support structure 17 through any conventional blocking medium 18 such as LMP alloy, pitch or the like.

In order to simplify the explanation of the present invention it will be assumed hereinafter that the lens blank 14 is rigidly supported in position while tool 11 is adapted to be moved relative to it. In practice, however, either the lens blank or the tool can be moved with respect to the other element or both may be moved. The present invention is concerned only with the relative movement between the two elements.

Referring still to FIG. 3, tool 11 is rapidly rotated about its central axis 19 at any conventional speed, usually from 5 to 10 thousand RPM, by means of a suitable drive motor 21 in order to provide the necessary abrasive action on the lens surface. This rotating tool is then moved across the surface 16 of lens blank 14 in a compound motion that will result in the desired toric shape being generated.

One part of this compound motion consists of oscillating the tool about a first axis 22 by means of a motor 24 such that the abrasive surface of the tool will move back and forth across the surface of the lens blank in a first curved path 23. Axis 22 is shown as being perpendicular to the plane of the Figure, however, as will be explained hereinafter, this is not essential. The position of axis 22 relative to the lens surface is selected such that the radius R_1 of the curved path 23 will correspond to the radius of the curvature to be generated on the lens surface 16 in the direction of one major meridian, preferably the cylinder meridian, which, in the embodiment illustrated will be the meridian perpendicular to the plane of the Figure. The center of curvature of the surface 16 in the direction of that meridian and having a radius R_1 is indicated at C_1 and it can be seen that the axis 22 about which the tool is oscillated passes through C_1, i.e., radius R_1 is equal to $V-C_1$, the distance between the vertex V of the desired toric surface and the center of curvature C_1. Furthermore, the tool is oriented relative to the lens surface such that it will be oscillated back and forth across surface 16 of the lens blank within a plane parallel to and generally including axis 19 of the tool so that essentially the entire abrasive face of the tool (as opposed to merely an edge) is operative in generating a spherical curvature having a radius R_1 on the surface 16 in the direction of one major meridian of the lens surface. By being oriented in this way, the tool does not present an edge to the lens surface as in the prior art and, thus, will avoid the formation of ridges or grooves on the lens surface.

This oscillating motion, in and of itself will produce a spherical surface and not a toric one. To form a true toric surface the tool must also be swept across the lens surface 16 in a second curved path. This sweeping motion is carried out simultaneously with the oscillating motion and generally at a slower rate. More particularly, as shown in FIG. 3, the tool is also swept around an axis 26 by a suitable drive motor 27 in a curved path 28 having a radius R_2. Axis 26 is also perpendicular to the plane of the Figure and is positioned on the vertex axis of the toric surface and spaced from the vertex of the desired toric surface by a distance equal to the radius of curvature desired for the base curve of surface 16. In other words, axis 26 is positioned to extend through the center of curvature C_2 so that R_2 will equal $V-C_2$, the radius of the curvature desired in the direc-

tion of the second major meridian of the lens surface, generally the base meridian.

By employing the above-described compound motion of oscillating the tool back and forth relative to the lens surface while simultaneously sweeping it across the lens surface, a true toric curvature may readily be generated. The surface so produced will not have any elliptical error that would require later truing operations. Furthermore, the surface will not have the grooves or ridges produced by many of the prior art techniques that also necessitate further treatment to the lens. In addition, the relatively simple kinematics of this system makes it a simple matter to generate toric surfaces of widely varying curvature. With the present invention, to obtain a toric surface having different curvatures than are illustrated in FIG. **3**, it is only necessary to provide curved paths of different radii. There is no need to control any angular relationship between the tool and the lens surface nor the effective diameter of the tool as in the prior art.

In FIG. **3**, both the oscillating motion along curve **23** and the sweeping motion along curve **28** are shown as being in the same plane. This has been done only for ease of explanation. Theoretically, the relative orientation of the oscillating motion axis and the sweeping motion axis is immaterial as long as they intersect the desird centers of curvature C1 and C2, respectively. In practice, however, it is generally preferable that they be chosen to be either parallel as illustrated in FIG. **3** or perpendicular to one another.

In a typical operation of the system as a grinding tool, the grinding tool is rotated about its axis at a velocity of from about 5 – 10 thousand RPM. It is oscillated back and forth around axis **22** at a rate of about 100 – 200 cycles per minute. The sweeping motion is carried out at a much slower rate of one sweep across the lens surface in 30 – 60 seconds. With such an operation the removal of a glass layer of about 3 millimeters from a 60 millimeter diameter blank requires between 30 to 60 seconds.

The specific structure for performing the various movements illustrated in FIG. **3** has not been illustrated in order to simplify the description of the invention and also because it could take many forms readily recognizable by those skilled in the art. As an example, however, it would be possible to employ a system similar to that illustrated in FIG. **1** of U.S. Pat. No. 2,633,675 although the tool of that FIG. would have to be reoriented so as not to be tilted relative to the face of the lens. Other structural embodiments would readily be apparent to those skilled in the art in order to cause either the tool or the lens or both to be moved in the prescribed path relative to each other.

It should also be understood that the embodiment illustrated in FIG. **3** is intended to be a preferred embodiment only and, as discussed above, it could take a variety of other forms. Accordingly, it should be understood that the present invention should be limited only as required by the scope of the following claims.

I claim:

1. Apparatus for generating a toric surface on a workpiece comprising:

a. means for supporting a workpiece upon which said toric surface is to be generated;

b. means for supporting a cup-shaped surfacing tool adjacent said workpiece for generating said toric surface thereupon, the surfacing face of said tool being symmetrical about a central tool axis;

c. first drive means for transversely oscillating said tool and said workpiece relative to one another in a first curved path having a radius equal to the radius of curvature to be generated along a first major meridian of said toric surface, said first drive means including means for oscillating said tool and said work piece relative to one another in a plane that always includes said tool axis; and

d. second drive means for transversely sweeping said tool and said work piece relative to one another in a second curved path having a radius equal to the radius of curvature to be generated along a second major meridian of said toric surface and about an axis that extends through the vertex axis of the toric surface to be generated.

2. Apparatus as recited in claim **1** wherein the radius of said first curved path is less than the radius of said second curved path.

3. Apparatus as recited in claim **1** wherein said first drive means includes means for driving said tool and said work piece relative to one another at a faster rate than said second drive means.

4. Apparatus as recited in claim **1** wherein said first and second drive means drive said tool and said work piece relative to one another in parallel planes.

5. Apparatus as recited in claim **1** wherein said first and second drive means drive said tool and said work piece relative to one another in planes that are perpendicular to one another.

6. Apparatus as recited in claim **1** and further including third drive means for rotating said tool about said tool axis.

7. Apparatus as recited in claim **1** wherein said tool comprises a grinding tool.

8. Apparatus as recited in claim **1** wherein said work piece comprises a lens blank.

9. A method for generating a toric surface on a work piece comprising:

a. supporting a work piece upon which said toric surface is to be generated;

b. supporting a cup-shaped surfacing tool adjacent said work piece for generating said toric surface thereupon;

c. oscillating said tool and said work piece relative to one another in a plane that includes the axis of said tool and along a first curved path having a radius equal to the radius of curvature desired in the direction of a first major meridian of said toric surface; and

d. simultaneously sweeping said tool and said work piece relative to one another in a second curved path having a radius equal to the radius of curvature desired in the direction of a second major meridian of said toric surface and about an axis that extends through the vertex axis of said toric surface to be generated.

10. A method as recited in claim **9** wherein said tool and said work piece are oscillated relative to one another in a plane parallel to and including said tool axis.

11. A method as recited in claim **9** wherein said tool and said work piece are oscillated relative to one another in a curved path having a radius that is less than the radius of the curved path along which said tool and work piece are swept relative to one another.

12. A method as recited in claim 9 wherein said tool and work piece are oscillated relative to one another about an axis that extends through the center of curvature of the curved surface desired in the direction of said first major meridian.

13. A method as recited in claim 9 wherein said oscillating and sweeping steps are performed in planes that are parallel to each other.

14. A method as recited in claim 9 wherein said oscillating and sweeping steps are performed in planes that are perpendicular to one another.

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